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A COMPARISON OF ALPINE TUNDRA FLORAS: N.E. CHINA AND N.W. NORTH AMERICA

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Introduction

Much has been written on the affinities of the floras of eastern Asia and of southeastern North America, with recent contributions to the subject appearing in Numbers 3 and 4 of the Missouri Botanical Garden Annals (1983). Although the many distribution maps of HULTÉN (1968) show remarkable similarities east and west for the northern part of the Pacific rim, few studies have examined the affinities of the disjunct floras in northeast Asia and in northwest North America.

In this article we compare in a preliminary way the flora of the Alpine Tundra zone on Changbai Mountain (Changbaishan) in northeastern China with several selected alpine and arctic floras of northwestern North America.

Description of Changbai Mountain

Changbaishan on the border of North Korea is the highest mountain in Jilin province and in northeast China (fig.1), rising to an altitude of 2691 m above sea level at north latitude 42°, longitude 128°. A volcanic peak, it has erupted three times in the last 400 years - in 1597, 1668, and most recently in 1702. The caldera is occupied by Heaven Lake, a blue transparent body of water with a maximum depth of 300 m.

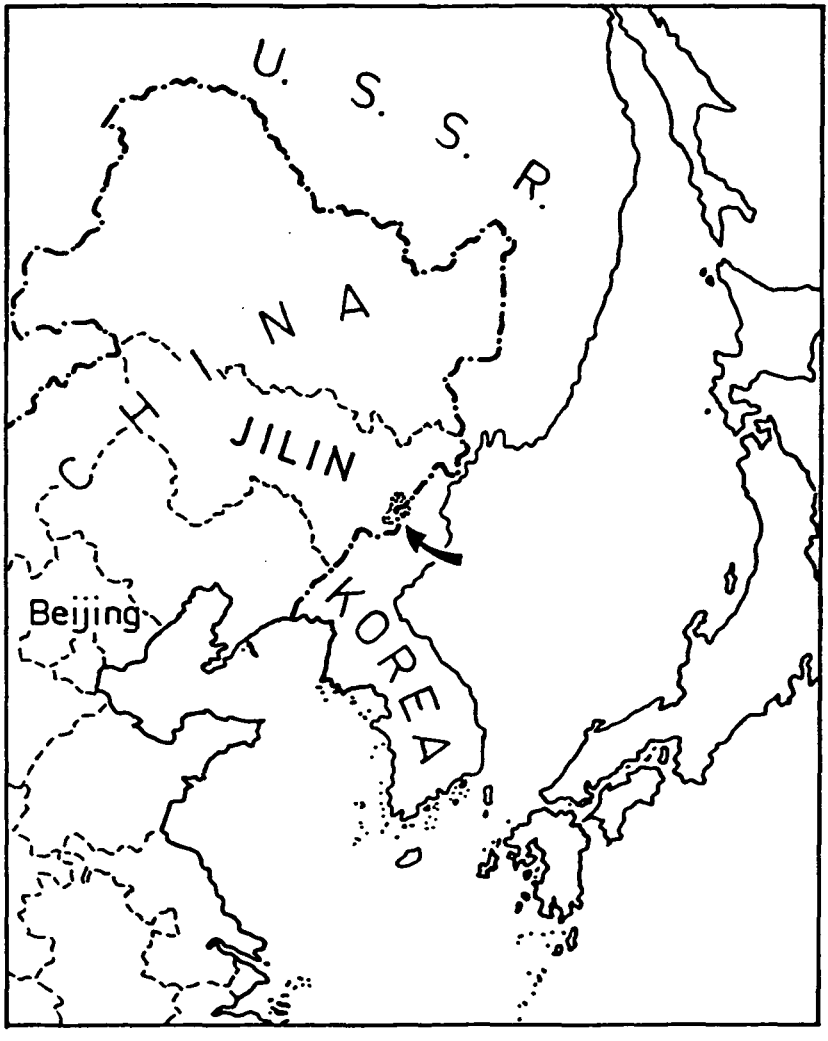

Fig.1. Northeast-China, location of Changbaishan on the border between province Jilin and North-Korea (arrow).

Debris-covered basaltic and scoria cliffs surround the lake and rise some 400 m. above its surface.

Except for the active talus slopes, the cliffs and the truncated valley spurs that indicate past glacial activity, and despite a history of vulcanism that has produced areas of pumice-and-ash substrate unsuitable for plant growth near the caldera rim, Changbaishan is well vegetated. Ascent of the mountain from the west side reveals the following zonation of communities on the deeper soils (fig.2):

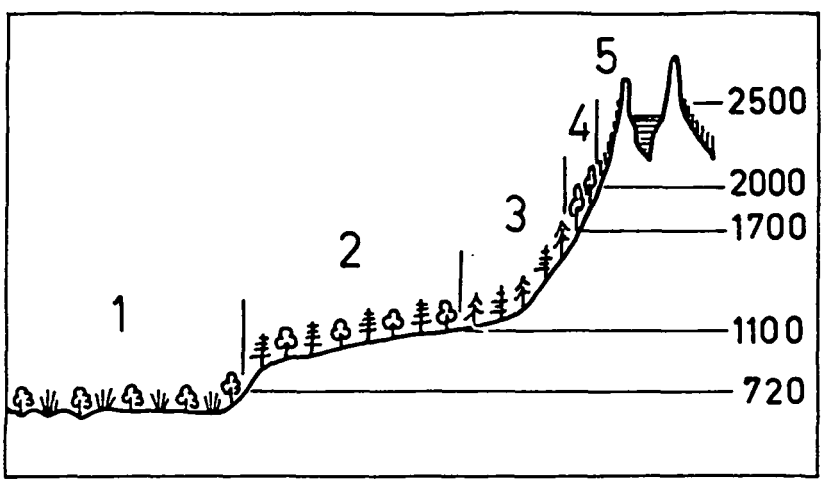

Fig.2. Changbaishan, profile of vegetation from west (left) to east (right):
1 = Scrub Forests of Quercus mongolica and Corylus heterophylla;
2 = Pine-Hardwood Forests;
3 = Coniferous Forests;
4 = Subalpine Birch Forests (including birch krummholzt on the forest line);
5 = Alpine "tundra" (Ericaceae dwarf shrubs and alpine meadows).

1. Less than 720 m altitude
   Scrub Forest of *Quercus mongolica* and *Corylus heterophylla*

2. From approximately 720 to 1100 m
   Pine-Hardwood Forest, with *Pinus koraiensis*, *Populus davidiana*, *Betula platyphylla* prominent on the drier sites, and with a rich mixture of temperate broadleaf species such as *Tilia amurensis*, *Acer mono*, *Fraxinus mandshurica*, *Ulmus propinqua*, and *Juglans mandshurica* occupying the moister sites. This forest bears many similarities to the forests of southeast Canada and the Lake States, USA.

3. From approximately 1100 to 1700 m
   Coniferous Forest, with pure or mixed species stands of *Larix olgensis*, *Picea jezoensis*, *Abies nephrolepis*, *Pinus sylvestris* var. *sylvestriformis*, plus several other spruce, fir and pine species. Some of the lower zone trees (*Pinus*, *Populus*, *Betula*) are conspicuous invaders after fire and other disturbance. The forest shows obvious relationships to the taiga and to the southern boreal fores in Canada.

4. From approximately 1700 to 2000 m
   Subalpine Birch Forest, dominated by *Betula ermanii*, with occasional *Pinus pumila*, *Alnus mandshurica* (= *A. crispa*), and *Sorbus decora*. At their upper limit, the birch groves assume the wind-trained krummholz form. Such a birch zone is uncommon in Alaska and in Canada, although it frequently occurs at high altitudes and high latitudes in the Fenno-Scandian countries and in the USSR.

5. Above 2000 m
   Alpine tundra, dominated by dwarf ericaceous shrubs, willows, and many herbaceous plants. The flora of this fifth zone is the center of interest in the remainder of the article.

A general description of the vegetation of China is given by Hou (1983) who specifically refers to the Changbaishan alpine vegetation (p.528) as "Mountain Dwarf-Shrub Tundra". According to him, similar tundra with evergreen dwarf-shrubs and mosses occurs on the summits of other temperate high mountains in the Altai and Khingan ranges where "the soil is acid, and the climate is characterized by high humidity, strong winds, a short growing season, and local permafrost".

Whether or not permafrost occurs on Changbaishan, solifluction is certainly a force on the rolling uplands. Small breakaway scarps and terraces plus the ericaceous cover give the high altitude landscapes an aspect similar to the moister parts of the low arctic in North America.

Methods

The senior author and his co-workers and students at Northeast Normal University, Changchun in Jilin province, have been interested in the flora of Changbaishan for many years and have made extensive collections of plants there. In 1979 a check-list was published by QIANG JIAJU & CHANG-WEN-ZHONG, including 1243 species. Of these, 96 occupy the Alpine Tundra zone and for the purposes of this article they constitute the community to be compared to high latitude and high altitude floras in northwestern North America.

Comparisons were made using three North American floras: that of HULTEN (1968) for Alaska and the neighboring Territories in Canada, PORSILD & CODY (1982) for the Northwest Territories, and MOSS & PACKER (1983) for the Rocky Mountains of western Alberta.

In the four-way comparison, species names within genera were used solely, because of difficulties in determining subspecies and varietal synonyms. Even at the species level some problems were encountered. As two examples, *Juniperus sibirica* BURGSD. and *J. communis* were taken to be synonyms as were *Empetrum sibiricum* V. VASSIL. and *E. nigrum* L., although the literature suggests that not all authorities would agree.

Comparison of the flora of the alpine tundra zone on Changbai Mountain in North-East China with the floras of selected alpine zones in North-western North America

Alpine Tundra of Changbai Mountain	Alaska and Neighboring Territories	Northwest Territories Canada	Rocky Mountains Alberta, Can.
Lycopodiaceae			
Lycopodium alpinum L.	+	+	+
Lycopodium chinense CHRIST.			
Lycopodium selago L.	+	+	+
Woodsiaceae			
Woodsia ilvensis (L.) R.BR.	+	+	+
Cupressaceae			
Juniperus sibirica BURGSD.	+	+	+
Salicaceae			
Salix oblongifolia TR.& MEY.			
Salix polyadenia HAND-MAZZ.			
Salix pyrolifolia LEDEB.			
Salix rotundifolia TRAUTV:	+	+	
Polygonaceae			
Bistorta ochotensis KOM.			
Polygonum viviparum L.	+	+	+
Oxyria digyna (L.) HILL.	+	+	+
Pleuropteropyrum ajanensis NAKAI			
Caryophyllaceae			
Cerastium baishanense Y.C.CHU			
Minuartia arctica (STEV.) ASCH. & GRAEBN.	+	+	
Minuartia macrocarpa (PURSH) OSTENF.	+	+	
Silene oliganthella NAKAI			
Silene repens PATR.	+	+	

Alpine Tundra of Changbai Mountain	Alaska and Neighboring Territories	Northwest Territories Canada	Rocky Mountains Alberta, Can.
Ranunculaceae			
Aquilegia japonica NAKAI & HARA			
Ranunculus borealis TRAUTV.	+	+	+
Papaveraceae			
Papaver pseudo-radicatum KITAG.			
Cruciferae			
Arabis coronata NAKAI			
Cardamine resedifolia L.			
Draba borealis DC.	+	+	+
Crassulaceae			
Orostachys mallacophyllus (PALL.) FISCH.	+		
Rhodiola sachaliensis A.BOR.	+		
Sedum rosea (L.) SCOP.	+		+
Saxifragaceae			
Chrysospleniu m kamtschaticum FISCH.	+		
Parnassia palustris L.	+	+	+
Saxifraga laciniata NAKAI			
Saxifraga punctata L.	+	+	
Saxifraga takedana NAKAI			
Rosaceae			
Dryas octopetala L.	+	+	+
Potentilla nivea L.	+	+	+
Sanguisorba sitchensis C.A.MEY.	+	+	
Sibbaldia procumbens L.	+	+	+
Fabaceae			
Hedysarum alpinum L.	+	+	+
Oxytropis anertii NAKAI			
Empetraceae			
Empetrum sibiricum V.VASSIL.	+	+	+

Alpine Tundra of Changbai Mountain	Alaska and Neighboring Territories	Northwest Territories Canada	Rocky Mountains Alberta, Can.
Violaceae			
Viola biflora L.	+		
Umbelliferae			
Bupleuraum euphorbioides NAKAI			
Coelopleurum nakaianum (KITAG.) KITAG			
Coelopleurum saxatile (TURCZ.) DRUDE			
Tilingia tachiroei (FRANCH. & SAV.) KITAG.			
Ericaceae			
Arctous rubra (REHD.& WILSON) NAKAI	+	+	+
Ledum palustre L.	+	+	+
Phyllodoce coerulea BAB.	+	+	
Rhododendron aureum GEORGE			
Rhododendron confertissimum NAKAI			
Rhododendron parvifolium ADAMS.	+		
Rhododendron redowskianum MAXIM.			
Vacciniu m uliginosum L.	+	+	+
Vacciniu m vitis-idaea L.	+	+	+
Gentianaceae			
Gentiana algida PALL.	+		
Gentiana jamesii HEMSL.			
Labiatae			
Prunella asiatica NAKAI			
Scrophulariaceae			
Pedicularis verticillata L.	+	+	
Veronica stelleri PALL.	+		
Caprifoliaceae			
Linnaea borealis L.	+	+	+

Alpine Tundra of Changbai Mountain	Alaska and Neighboring Territories	Northwest Territories Canada	Rocky Mountains Alberta, Can.
Compositae			
Aster alpinus L.	+	+	+
Chrysanthemum zawadzkii HERB.			
Ligularia deltoidea NAKAI			
Ligularia jamesii (HEMSL.) KOM.			
Petasites saxatilis KOM.			
Saussurea alpicola KITAG.			
Saussurea alpina D.C.			
Senecio phoeanthus NAKAI			
Gramineae			
Agrostis trinii TURCZ.	+		
Anthoxanthum nipponicum HONDA			
Deschampsia caespitosa BEAUV.	+	+	+
Festuca subalpina CHANG & SKV.			
Festuca rubra L.	+	+	+
Hierochloe alpina ROEM. & SCHULT.	+	+	+
Poa arctica R.BR.	+	+	+
Poa shinanoana OHWI			
Ptilagrostis mongolica (TURCZ.) GRISEB.			
Trisetum spicatum (L.) RICHTER	+	+	+
Cyperaceae			
Carex atrata L.	+	+	+
Carex bipartita ALL.			+
Carex changbaishanica CHOU			
Carex eleusinoides TURCZ.	+	+	
Carex sedakovii MEINSH.			
Carex sirounensis KOIDZ.			
Kobresia bellardii (ALL.) DEGL.	+	+	+
Scirpus hudsonianus (MICHX.) FERNALD	+	+	+
Scirpus maximowiczii C.B.CLARKE			

Alpine Tundra of Changbai Mountain	Alaska and Neighboring Territories	Northwest Territories Canada	Rocky Mountais Alberta, Can.
Juncaceae			
Juncus maximowoczii BUCH.			
Luzula oligantha SAMUEL .			
Luzula pallascens (WHLB.) BESS.			
Luzula sudetica D.C.			
Luzula wahlenbergii RUPR.	+	+	+
Liliaceae			
Lloydia serotina (L.) REICHB.	+	+	
Lloydia triflora BAKER			
Tofieldia nutans WILLD.			
Zygadenus sibiricus (L.) A.GRAY			
Orchidaceae			
Coeloglossum viride HARTM.	+		+
Total Species Changbai Mt. = 96			
Species shared with Changbai Mt.:	49(51 %)	39(41 %)	32(33 %)

Results

An unexpectedly high number of species above 2000 m on Changbaishan occur also in northwestern North America, as shown in Table 1. The total listed complement of Changbai Mountain's Alpine Tundra species is 96, and the numbers (and percentages) of those shared with Alaska and neighboring territories is 49 (51 %), with the Northwest Territories in Canada is 39 (41 %), and with the alpine flora of the Rocky Mountains in western Alberta is 32 (33 %).

The decrease in numbers of species shared from Alaska to the Territories to the Alberta Rocky Mountains is that expected with increasing distance from Northeast Asia. The different land masses covered by each of the three northwest North America floras may contribute to

the numbers of shared species and, for example, the similarities to the Rocky Mountain flora might well be increased if the eastern British Columbian ranges were added to those of Alberta.

Had it been possible to carry out vegetational studies, comparing the prevalence of dominant species on Changbai Mountain with appropriate sample areas covered by the three North American floras, then even more striking similarities might have been revealed. The Alpine Tundra of Changbaishan is in large part dominated by ericoid vegetation - Rhododendrons with such well-known arctic-alpine species as *Empetrum nigrum*, *Arctous rubra*, *Ledum palustre*, *Phyllodoce coerulea*, *Vaccinium uliginosum*, and *V. vitis-idaea*. Such community types are also common in alpine and arctic North America, though lacking the richness of *Rhododendron* species.

Diskussion

The similarities in alpine/arctic floras east and west shown in this study may not appear at first glance to be exceptional. After all, the Bering Strait has had a dry land connection since Mesozioc times, and only recently has water been a barrier (HOPKINS 1967). Furthermore, since the end of the Cretaceous the Bering Strait area has been close to the rotational north pole which means that the major control over migrating flora and fauna must have been largely climatic (McKENNA 1983) with cold temperatures the strongest selective influence. One might therefore expect that cold-tolerant arctic/alpine species would be the most successful migrators between Asia and North America, particularly during the Pleistocene.

A glance at the map of China-Korea shows, however, that there is at least one topographic barrier on the presumed migration route. The mountain ranges of which Changbaishan is a part are isolated from other ranges farther north by the Manchurian Plain and the Amur River valley. Presumably elements of the arctic/alpine flora were able to cross these lowlands during glacial intervals close to the ice, when the forests retreated southward. With return of the forest during interglacials, such as the present, the tundra vegetation moved upward to survive

only on the high altitude, frost-stirred soils.

Nevertheless, considering the distances and the exigencies of migration for small plants, the similarities between Changbaishan's complement of species and the floras of the northwest in North America raise intriguing questions about the rapidity of evolution, the stability of species, and the geological history of the Pacific rim continents. KRUCKEBERG (1983) has suggested that much light might be thrown on the relationships of such vicariants and disjuncts through tests of genetic affinity by degree of crossability and interfertility.

According to HAMILTON (1983), "Many of the ambiguities (of geological history) are more likely to be resolved by paleobiogeographic studies than by geologic and geophysical ones". As the basis for paleobiogeographic studies, much more should be known about the affinities of the Pacific rim floras, and particularly of the amphi-Pacific species.

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